DOE SSL R&D Workshop - February 2016

Lighting and the Internet of Things - A Whirlwind Tour

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Alphabet Soup?

Standards and Technologies in advanced controls: OIC, Zigbee, ZLL, Zwave, POE, Thread …

Acronym of the Day: IOT = Internet of Things

Introduction to the fundamentals underpinning the IOT

Applying the IOT to Lighting

Focus on the example of commercial buildings

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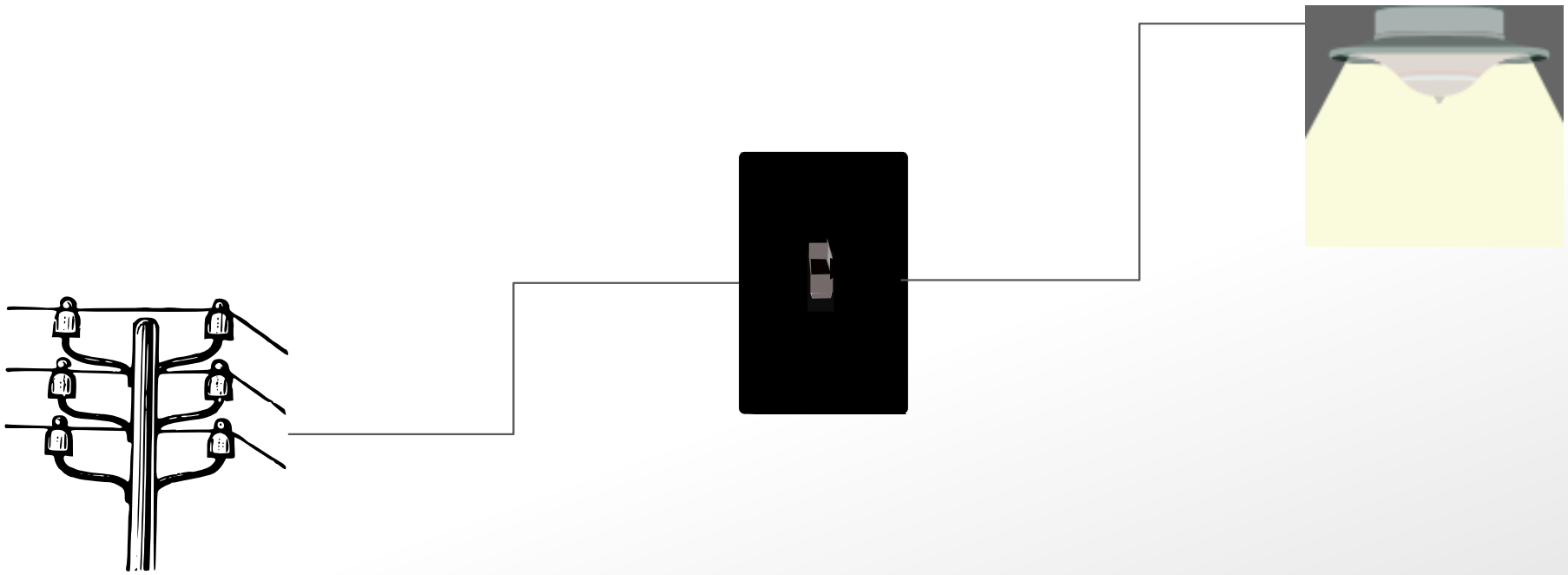
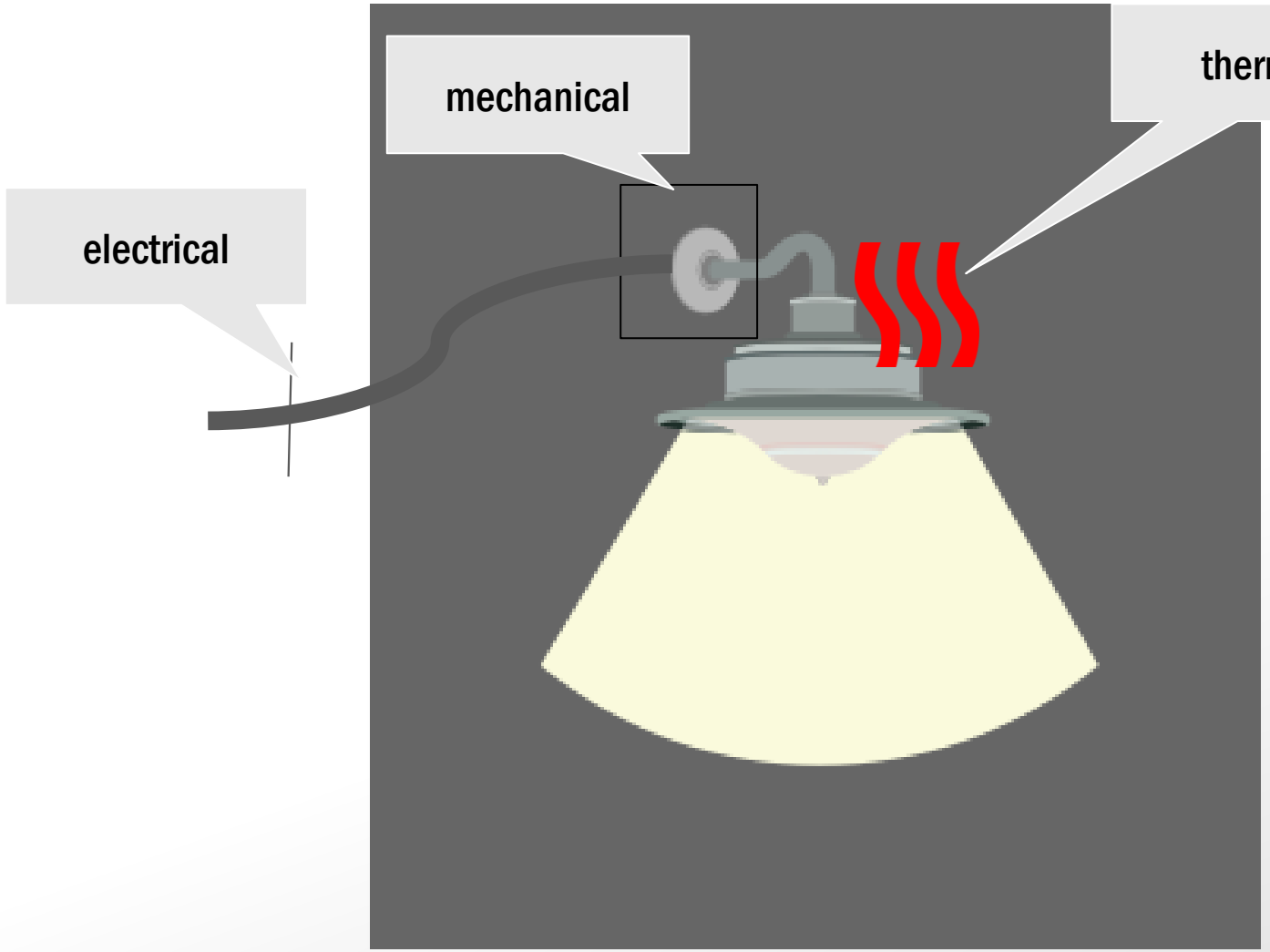
System Architecture – the Lighting world

Grossly oversimplified, of course



Consider a Luminaire – what are it's system interfaces?



Well-understood interfaces

Mature – nobody wants my 180V light?

Is the Optical interface a system interface?

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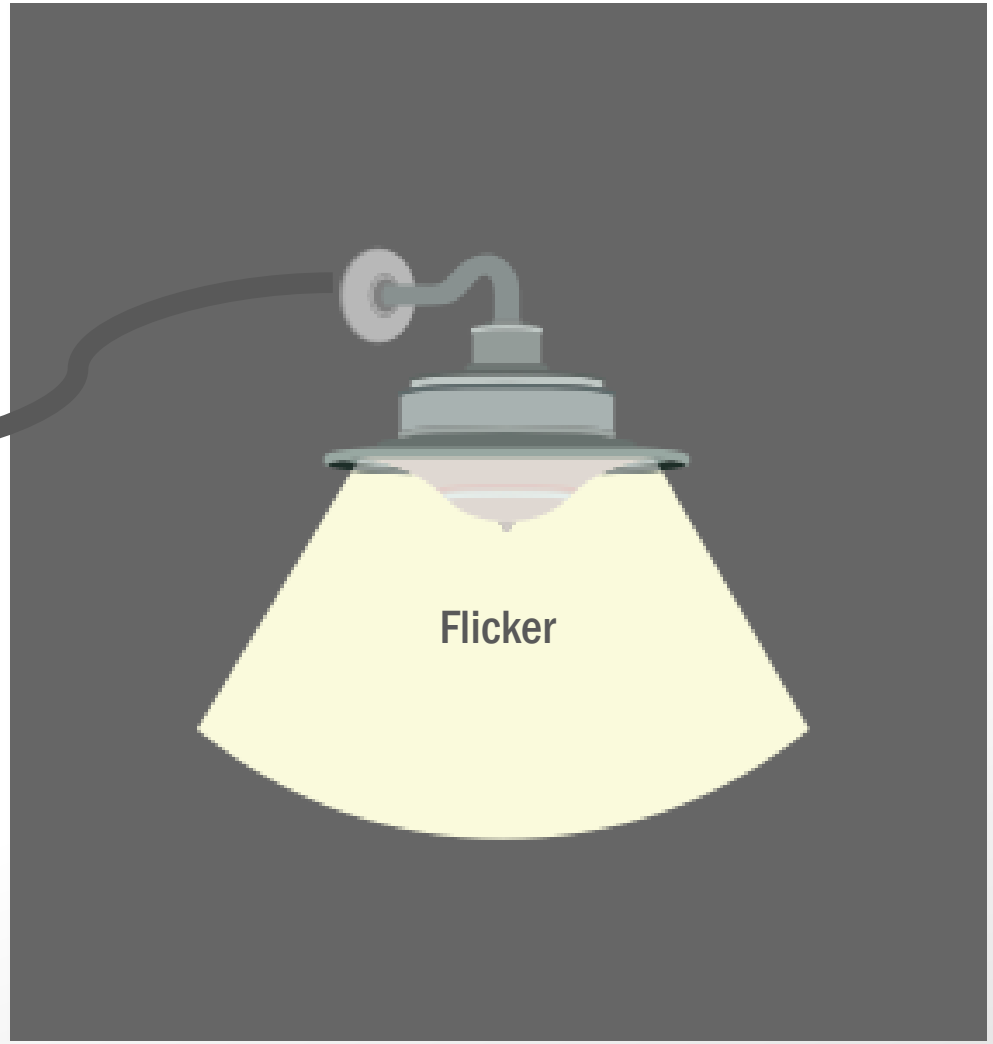
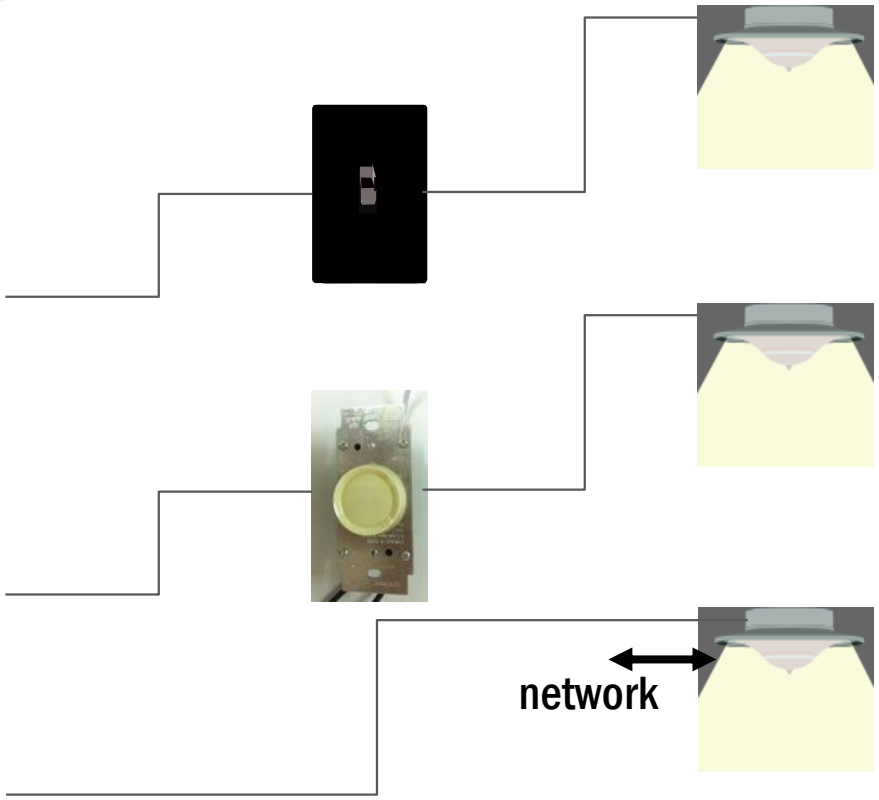
Is it all so easy?

Phase cut dimmer

Electrical interface



Information flow



Light Switch
2 bits / hour

Dimmer
24 bits / hour

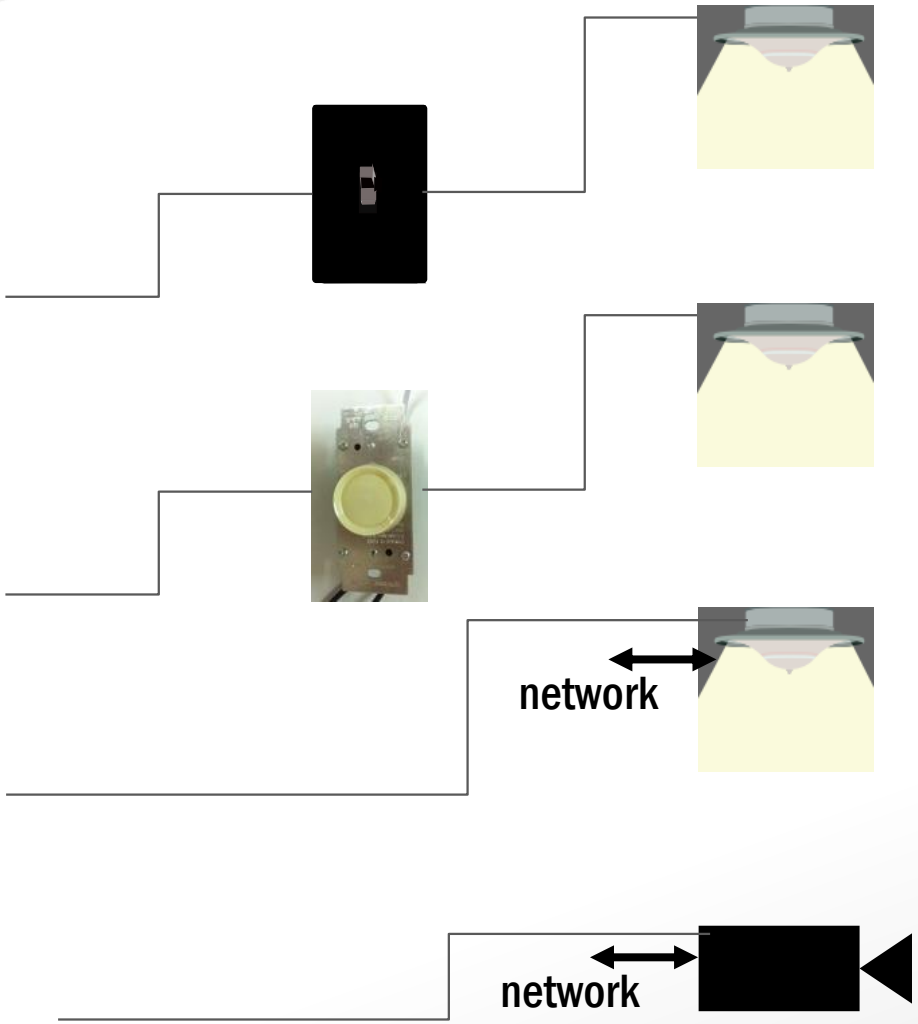
Networked Light Fixture / IOT Sensor
? bits / hour

So if it's only a few bits/hour, why do we need a fancy IOT network?

$/sq foot/month

Also, it doesn't have to be so fancy… Moore's law

Design Challenge



Light Switch
2 bits / hour

Dimmer
24 bits / hour

Networked Light Fixture / IOT Sensor
? bits / hour

Video Feed
7 billion bits / hour (2Mb/s, SD)

But that will be inordinately expensive, right?

Not really, since we have two very powerful nonlinearities on our side:

Moore's Law

The number of transistors in a dense integrated circuit doubles approximately every two years

Metcalfe's Law

The value of a telecommunications network is proportional to the square of the number of compatible communicating devices in the system (n^2)

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Don’t bet against Moore’s Law

Iphone 4 (2010)

Cray-2 1985

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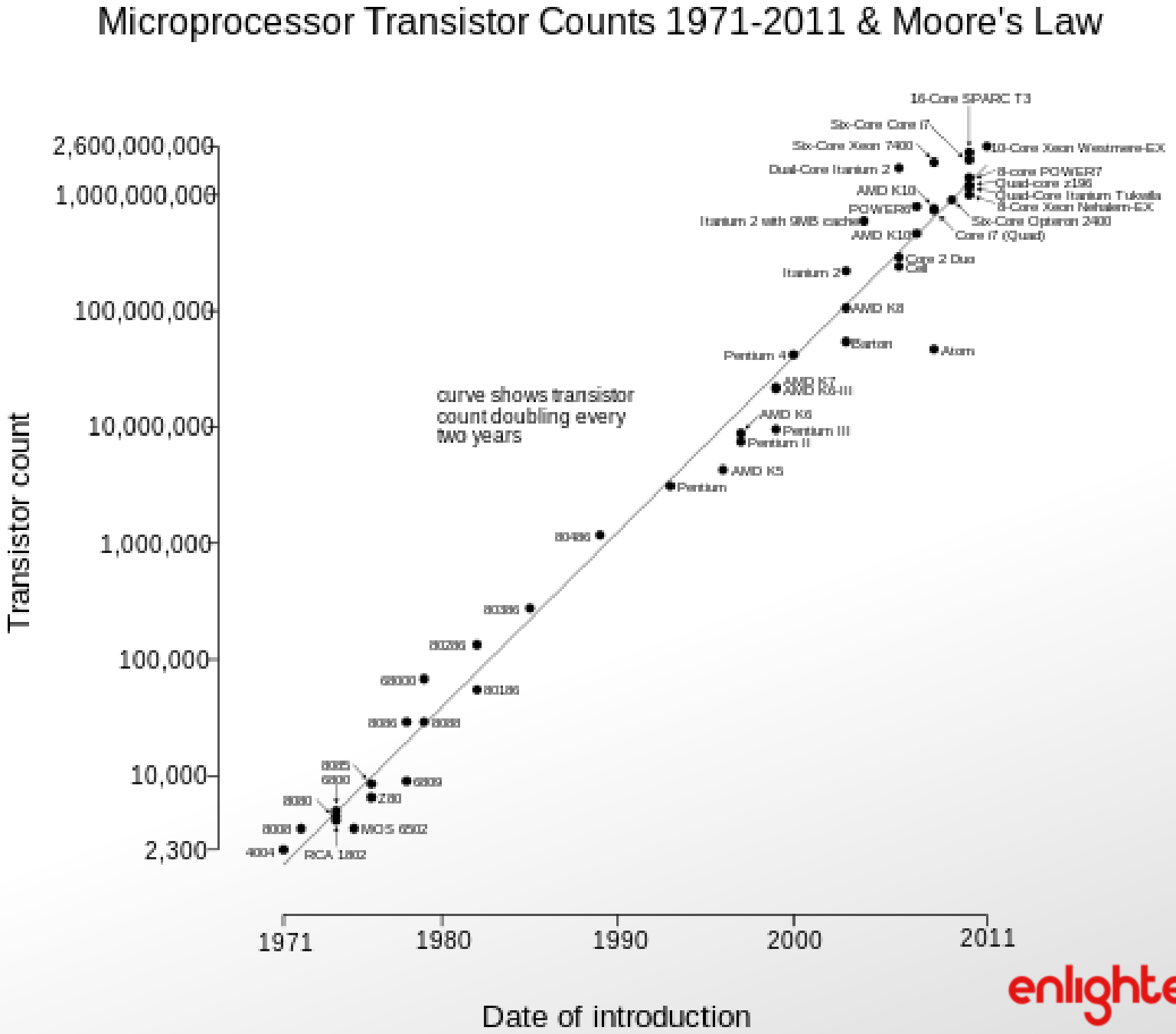
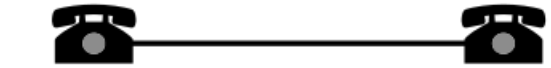
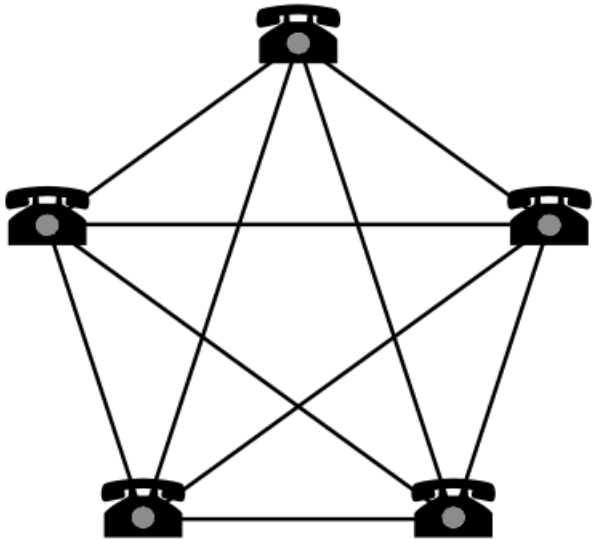


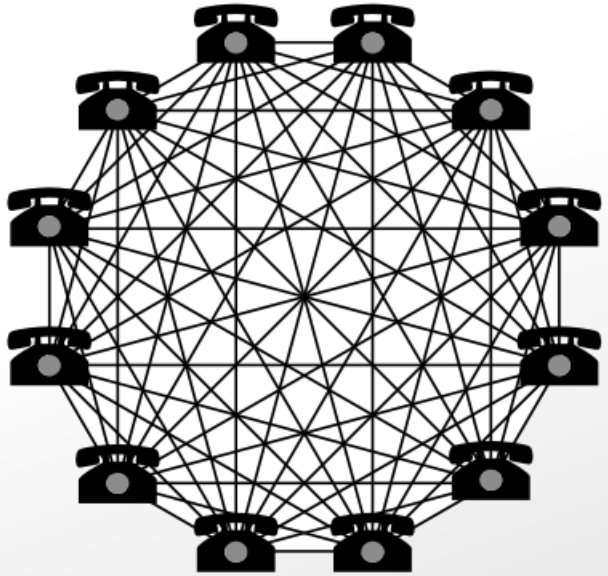
Metcalfe’s Law



Cost 2 Value 1



Cost 5 Value 10



Cost 12 Value 66

"Metcalfe-Network-Effect" by Woody993 at en.wikipedia - Transferred from en.wikipedia. Licensed under CC0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Metcalfe-Network-Effect.svg#/media/File:Metcalfe-Network-Effect.svg

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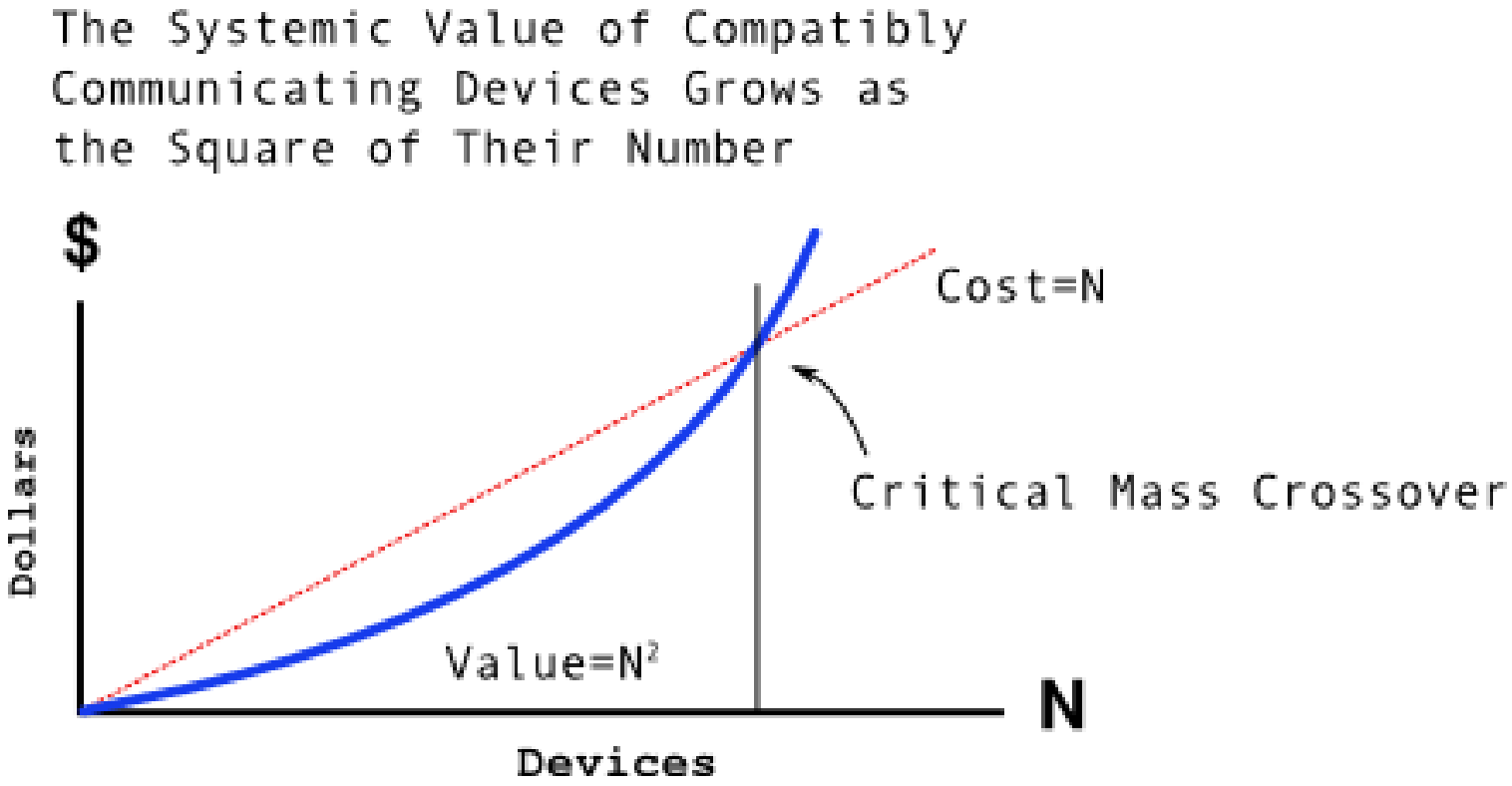
Metcalfe's Law



IOT Sensors

Things + the Internet

It's simple!

Each Sensor Node is a small computer

The Internet

Has:
Processing
Memory
Network Connection
Sensing

Doesn't Have:
User Interface

Highly Reliable
Low Cost
Low Power

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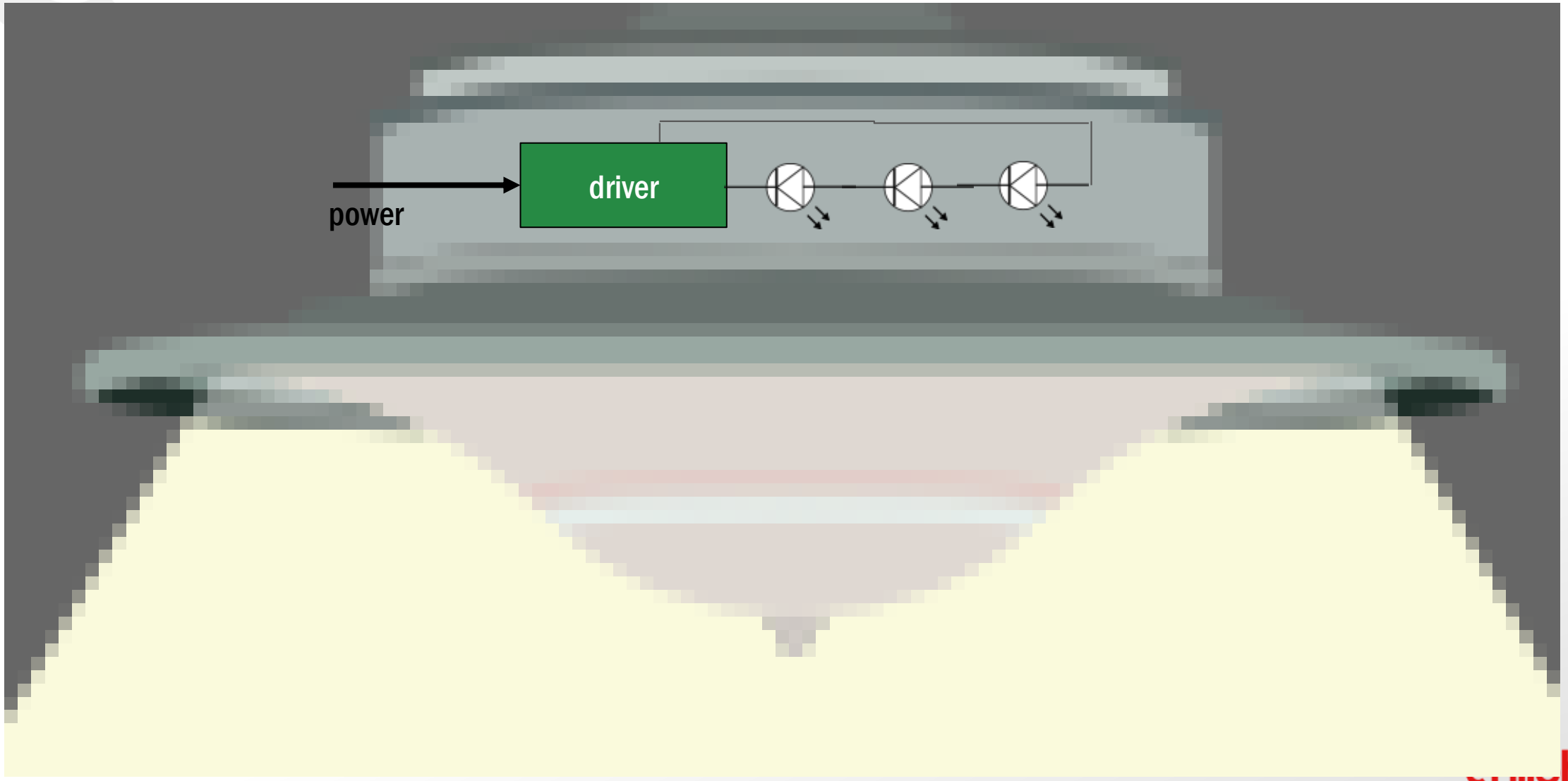
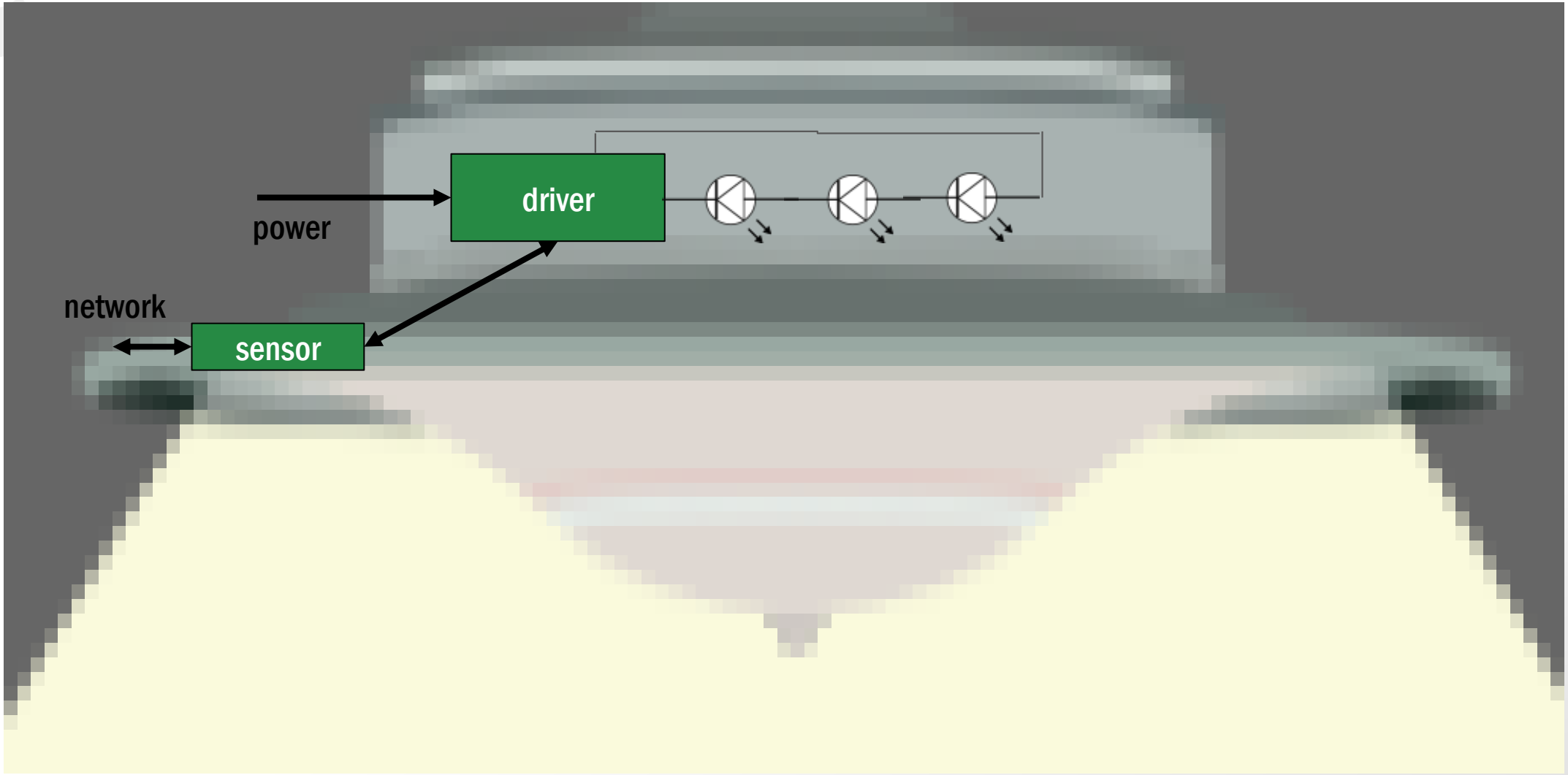
Inside the Luminaire



Inside the Connected/Smart/IOT Luminaire



IOT for Lighting - Requirements

Sensor

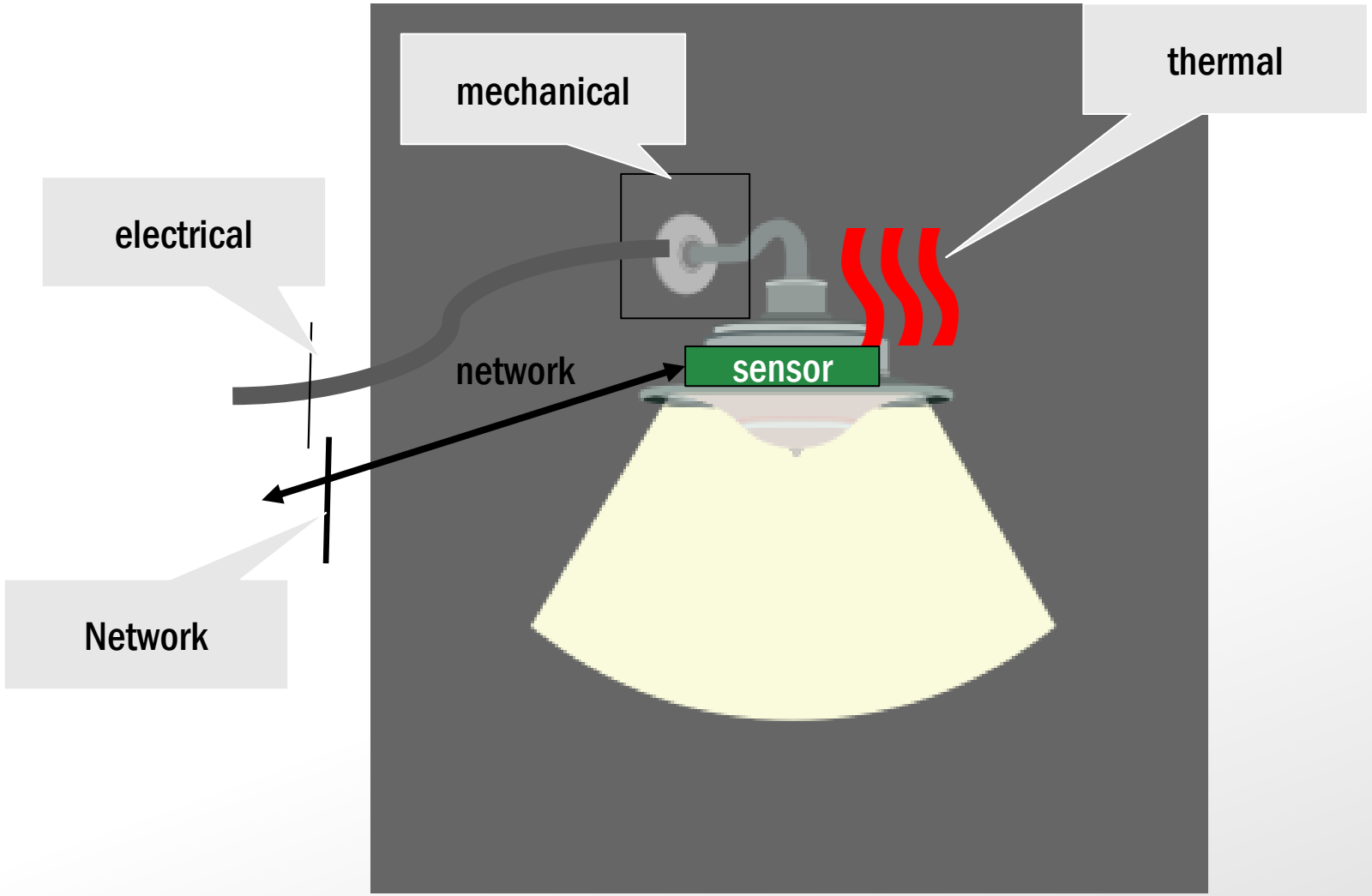
+ Low Cost
+ Accurate
+ Reliable : 15 Year Useful Life
+ Offline Survivable
+ Remote Software Upgradable
+ Easily Replaced
+ Future-proof

Network

+ Easy to Deploy Wireless
+ Highly Secure
+ Reliable
+ No Interference with WiFi
+ Scalable - Thousands of Sensors

Deterministic Behavior

Returning to Interfaces again – Connected Lighting Luminaire



What is *in* a Network Interface?

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

Network Interface

In general, a complex set of protocols (aka message formats or languages)

Each layer is its own protocol, and communicates directly with the layers above and below it

All layers must be compatible for two systems to communicate

The Internet Protocol (IP) suite (the basis of The Internet) is dominant for almost everything today

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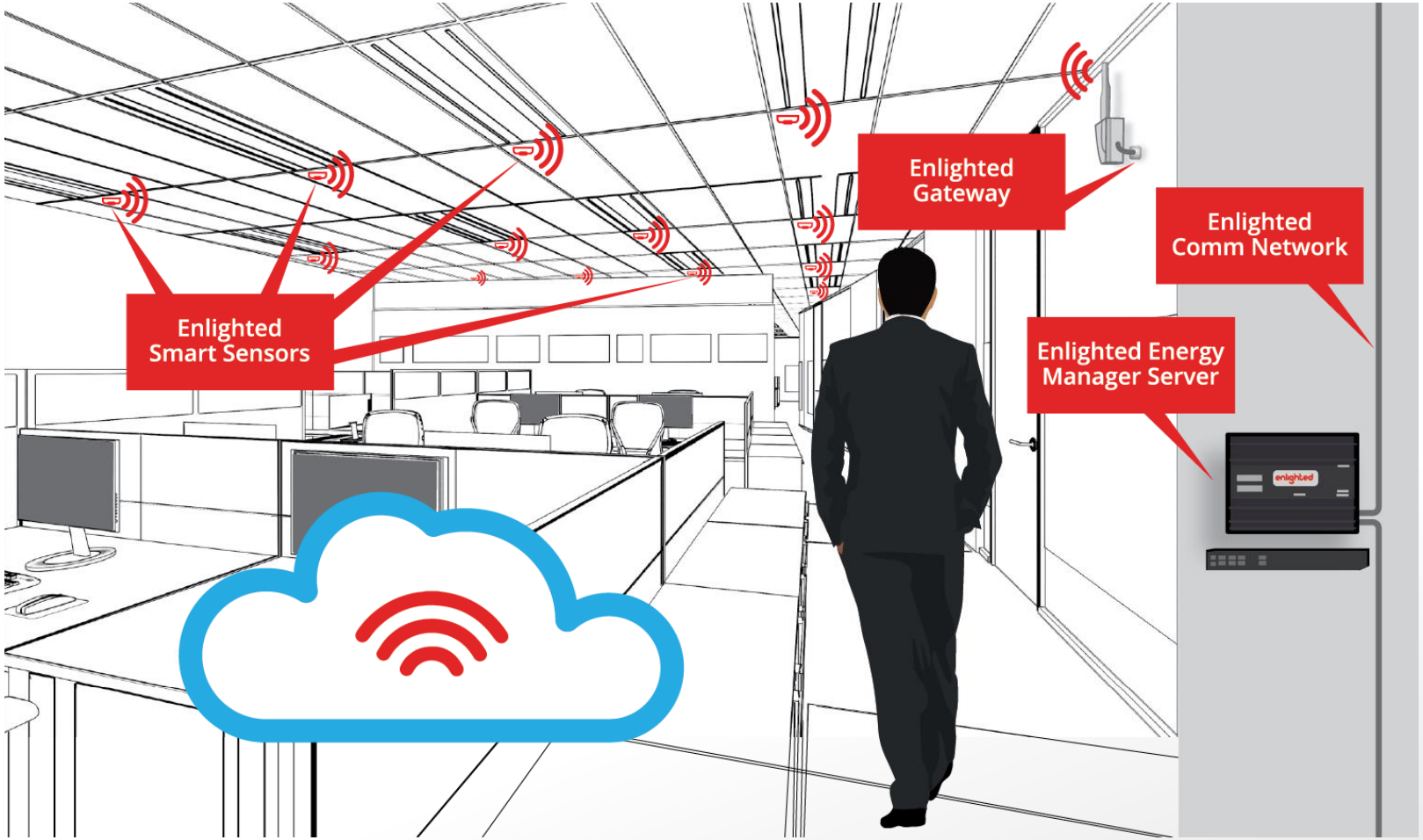
IOT in Lighting

An Advanced Wireless IOT System



Architecture:

- 1 Sensor Per Light Fixture Providing Power and Sensor Position
- Multi-Layered Signal Processing - Sensor / Gateway / Cloud
- Visibility into entire building

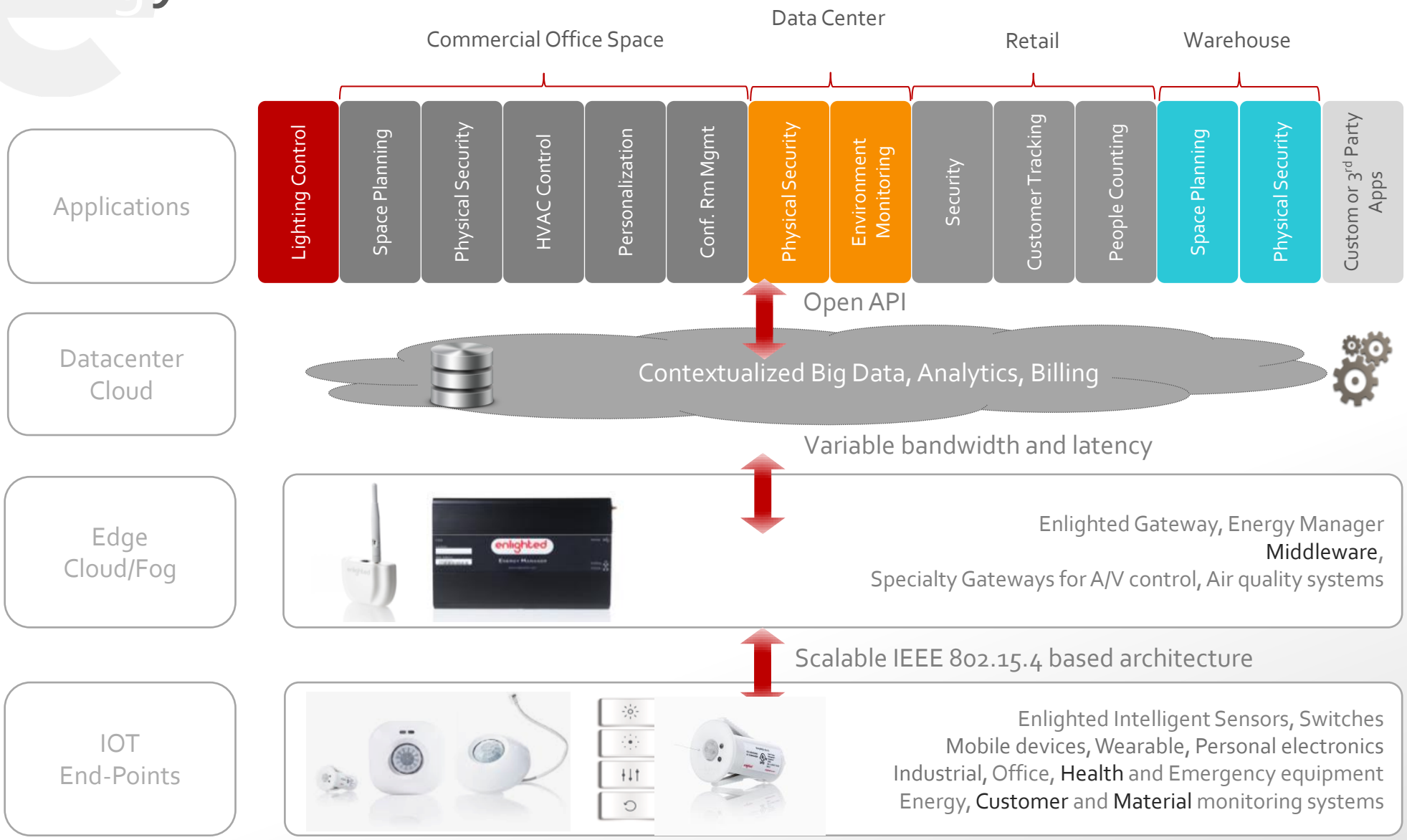
Wireless Network

- Capable of managing 1,000's of sensors
- Spectrum-efficient

24/7 Cloud Data Available:

- Metered Real-Time Data Sent to the Cloud
- Unlimited Compute Resources Available
- Apps Run in the Cloud

IOT System Architecture



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